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# A revolution in gas – The rise of the unconventionalals

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Presentation given at the Annual Convention of the Swiss Association of Petroleum Geologists and Engineers, Stresa, Italy, June 2010

**Key Words:** Gas, shale gas, unconventional gas, unconventional hydrocarbons, reach of world gas reserves, peak gas, peak oil, US gas production, European gas, world energy supply, horizontal drilling, fracking, source rocks, world energy.

## 1. Introduction

Predictions of world energy growth over the next decades range from 1.25% per year (AAPG, Scott Tinker, 2009) to 1.4% by IEA (<http://www.iea.org/>) and 1.5% by EIA (Burri 2008). Such a growth implies a doubling of the energy demand globally within the next 40 – 50 years, a challenge to which the world is as yet totally unprepared.

To illustrate the magnitude of the task: if energy requirements would double by 2050 and if – as a mental exercise – we were to supply all this energy exclusively through nuclear power plants, it would require one new 1 GW power plant every day for the next 40 years. Considering that there are at present some 440 nuclear power plants worldwide, many of which have a capacity well below 1 GW, the annual growth in nuclear power plants would, therefore, have to be equal to the entire presently installed worldwide capacity in nuclear power.

This exercise shows that:

- Such growth in nuclear energy supply is well beyond any realistically achievable technical and economical possibility;
- Whoever claims that the energy demand of this century can be resolved by the forced development of one type of energy source – be it nuclear, fossil or renewables – is speculating way outside realistic technical and economic boundary conditions (and is, thus, misleading the public);
- The magnitude of the task is such that the world energy sufficiency may not be obtained without a major conservation effort, i. e. higher efficiency in energy use and reduction in demand growth.

Until well after the year 2000 most experts assumed that the production of fossil hydrocarbon fuels was going to peak and then decline irreversibly over the next decades. Estimates ranged from an oil peak production at present (Peak Oil Organisation) to a peak in 10 – 25 years time (Oil companies, specialised government and consulting bodies). A gas peak was supposed to lag the oil maximum by some 10 years, so that by 2050 both oil and gas production would be in steep decline. It is only in very recent years

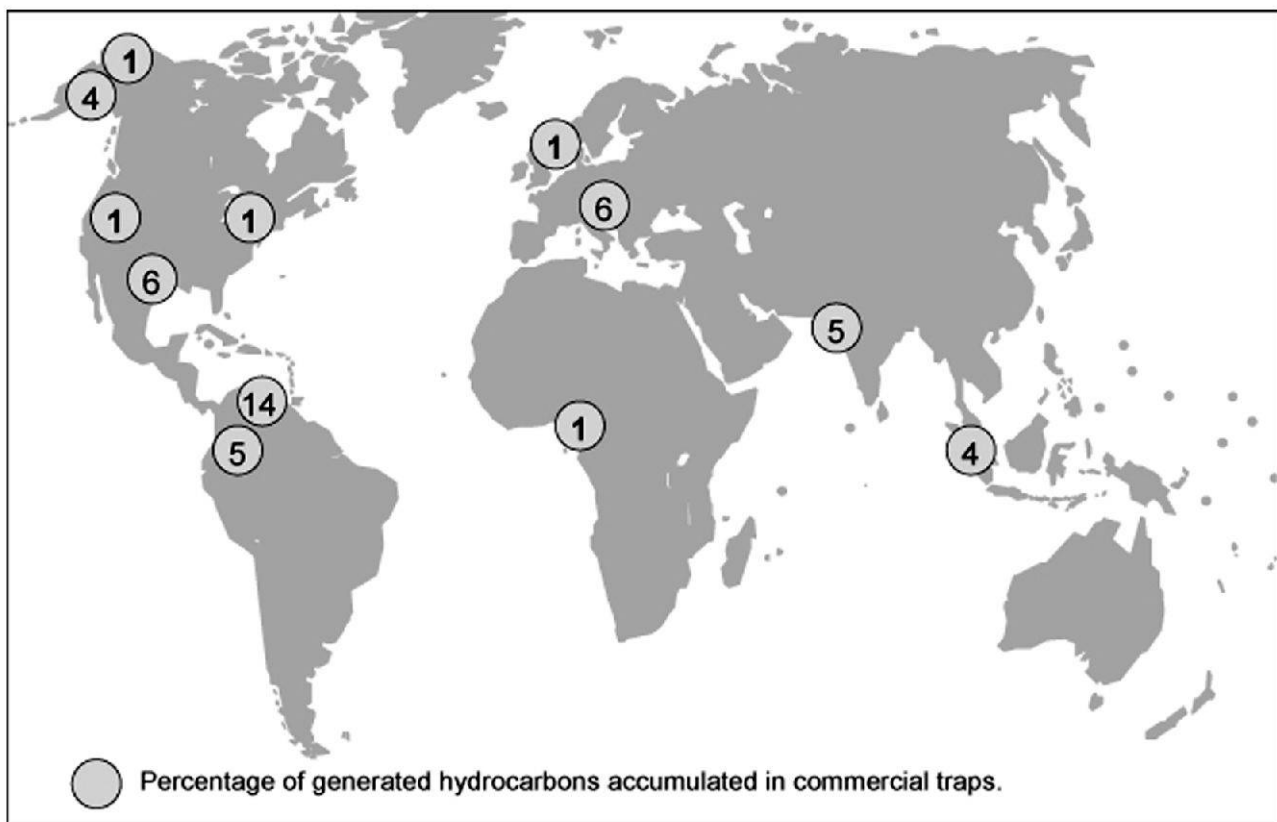
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that this view is being seriously challenged. While oil is likely to be heading for decline, though only after an extended decade-long plateau (determined more by world economy, available investments and by environmental restrictions than by the magnitude of producible resources), the scenario of gas may differ radically from previous predictions. The reason lies almost entirely in technology: progress in horizontal drilling and stimulation/fracking has led to a quantum leap in accessing unconventional gas in reservoirs previously considered non-producible.

«Shale gas» is the rising star of the unconventional exploration and is the main topic of the paper. (Note: many of the data for the presentation were compiled from web sites and not from official, published papers).

## 2. Wastezones – the new frontier in hydrocarbon exploration

The mechanism of generating, expelling, migrating and trapping hydrocarbons is generally a very wasteful process, both for oil and gas. Significant volumes remain in mature to post mature source rocks (SR), are lost in migration/remigration or leak to the surface where they evaporate or are destroyed. Only a minor part of the generated oil and gas is generally retained in conventional structural and stratigraphic traps. Even within the closure of traps, large amounts can accumulate in poor permeability wastezones (e. g. the Ten Boer Formation above the giant Groningen gas field) where they can generally not be produced conventionally. The word «wastezone» is here used in its largest sense, describing all hydrocarbon bearing rocks that have too low porosity/permeability properties to allow conven-



**Fig. 1:** Trapping efficiency in major oil and gas basins. Amount of generated hydrocarbons that have been trapped in conventional structural and stratigraphic traps. The remainder has leaked to surface, was lost in remigration or is still «stuck» in low permeability rocks [«wastezones»]. [Map courtesy of Prof. Harry Doust, Vrije Universiteit, Amsterdam NL. Data based on Magoon and Dow 1994].



tional production, e. g. source rocks, poor reservoir in closures (like tight gas sands), deep basin gas without actual trap and Coalbed methane.

Conventional hydrocarbon (HC) accumulations represent generally only a small fraction of the total HC generated in a basin. Magoon & Dow (1994) have analyzed many HC systems around the world and show that in most basins far less than 10% of the generated HC accumulate in reservoirs that can be produced economically by conventional means (Fig. 1). Trapping efficiency declines with the increasing complexity of migration paths, with higher degrees of tectonic deformation and with multiple tectonic phases, leading to remigration and redistribution of HC. Petroleum systems in tectonically quiet areas and, in systems that are closed within themselves and with juxtaposition of source rock, reservoir and regional seal (e. g. the Mesozoic petroleum systems in the Middle East) are likely to have a higher trapping efficiency, possibly up to several 10s of percent. Although the amount of HC originally generated remains a coarse estimate, it is safe to conclude that most petroleum systems have a highly inefficient «plumbing».

While some of the generated HC have – in geological times – been eroded or evaporated at the surface and some remain in the system as shows, significant volumes (possibly a multiple of the conventionally trapped HC) are contained in «wastezones», rocks that were so far of little interest to the oil and gas business but that are increasingly becoming the new frontier of the Industry.

### 3. Shale gas

Shale gas is contained in very large quantities in gas source rocks. Shale gas systems are source rock, reservoir, seal and trap in one. Gas is present as free gas in porespace and fractures and is adsorbed in organic matter. Shale gas systems have a too low permeability to be produced without artificial stimulation.

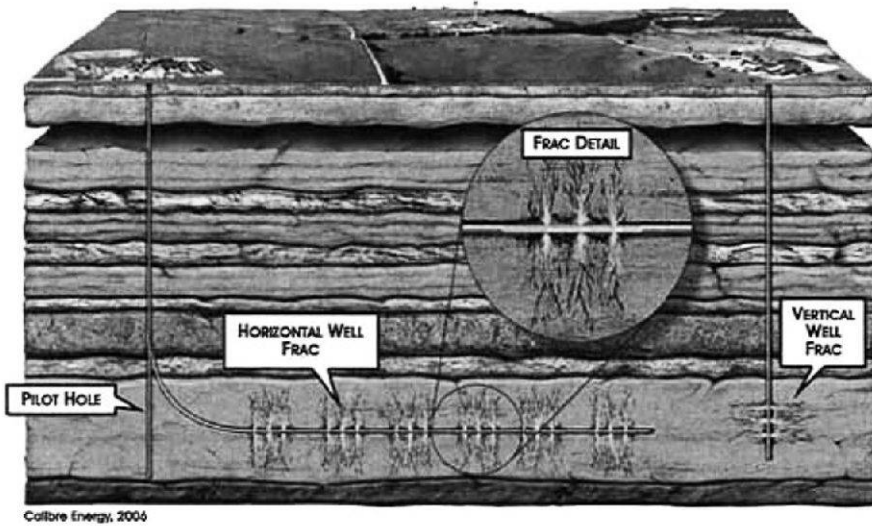
Criteria for a good shale gas rock are:

- High organic content (TOC > 2%).
- Fully mature source rock for type III organic matter and preferably overmature for type II.
- Thickness of several 10 m, preferably > 50 m.
- The rock must be brittle with a quartz or carbonate content of > 40%, so that it can be easily fraced.
- Presence of natural fractures.
- Deeper, overpressured SR have higher deliverability.

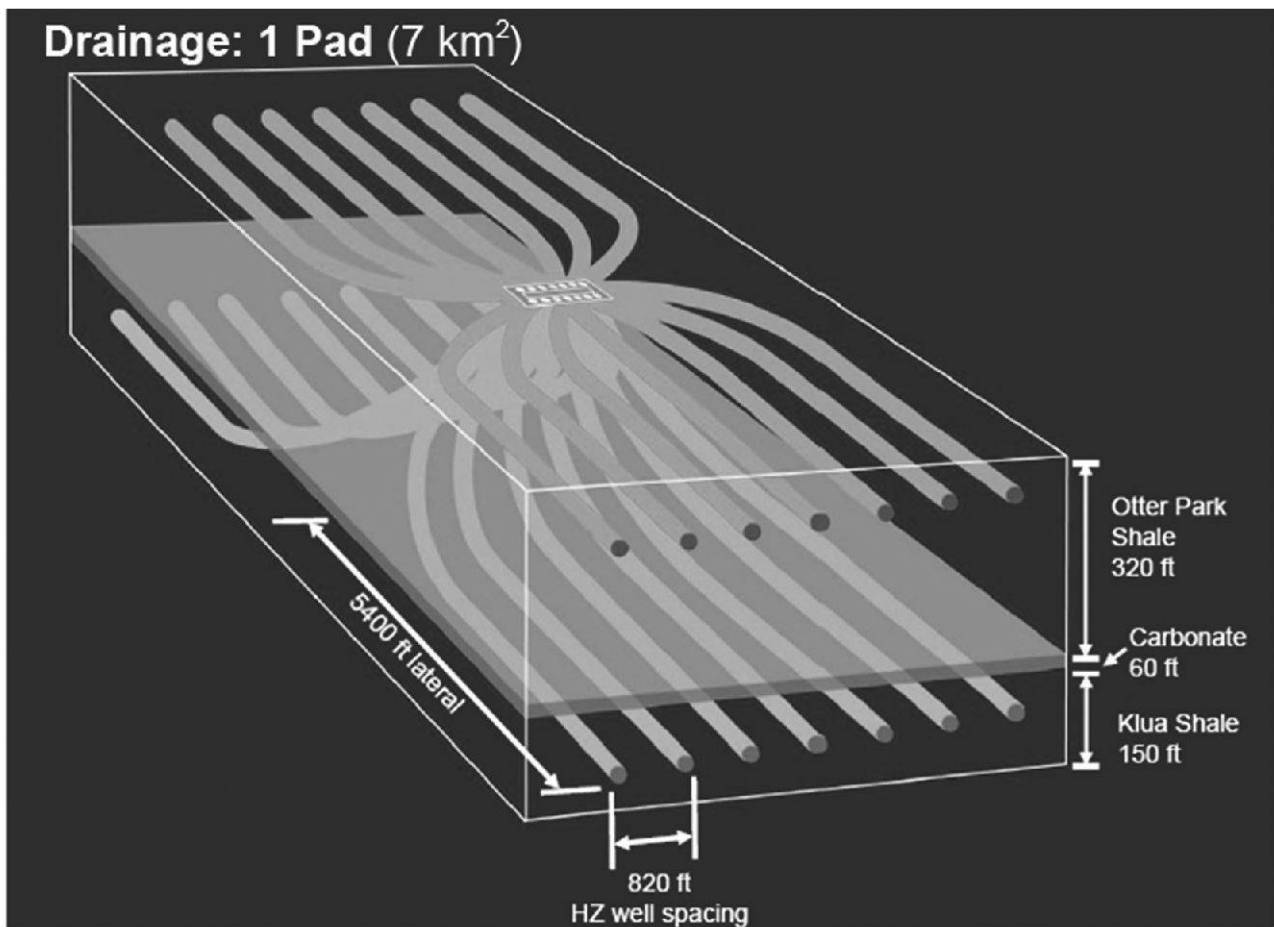
Shale gas rocks have high gas in place figures. US shale gas systems contain typically between 20 and 40 TCF of gas in place per km<sup>3</sup> of rock (oral communication Gazprom US).

The breakthrough in shale gas production is driven by technology. Advances in horizontal drilling and multi-fracing have led to production rates that are one or two orders of magnitude higher than in original vertical wells. Shale gas wells have typically horizontal legs of 1500 – 2500 m and contain more than 10 frac jobs (Fig. 2). In the US, drilling and completion of such wells at 2000 – 3000 m depth cost between 5 and 10 Mio USD.

Shale gas development requires very large drilling efforts. The Barnett Shale play counted at the end of 2009 over 13 000 wells that have so far delivered 1250 BCM (45 TCF) of gas. Over 95% of the wells drilled now are horizontal and multi-fraced. Newer developments use large numbers of multilateral wells, drilled from one drilling pad for optimal drainage (Fig. 3). A critical aspect is the use of water, an average stimulation requiring several million litres of water per frac. This may be a limiting factor in areas with scarce water resources.



**Fig. 2:** Shale gas development: the contribution of technology. Only long horizontal wells (up to several km) within the gas saturated, low permeability rock and multiple fracs (up to 10 – 20 per well) allow a commercial production of the previously unproducible resources [Courtesy of V. Neumann Gazprom Germania 2010].



**Fig. 3:** Shale gas development. Multiple horizontal well pad for optimal drainage in low permeability rock [Source: Apache, Web site, publications].



#### 4. Impact on the US

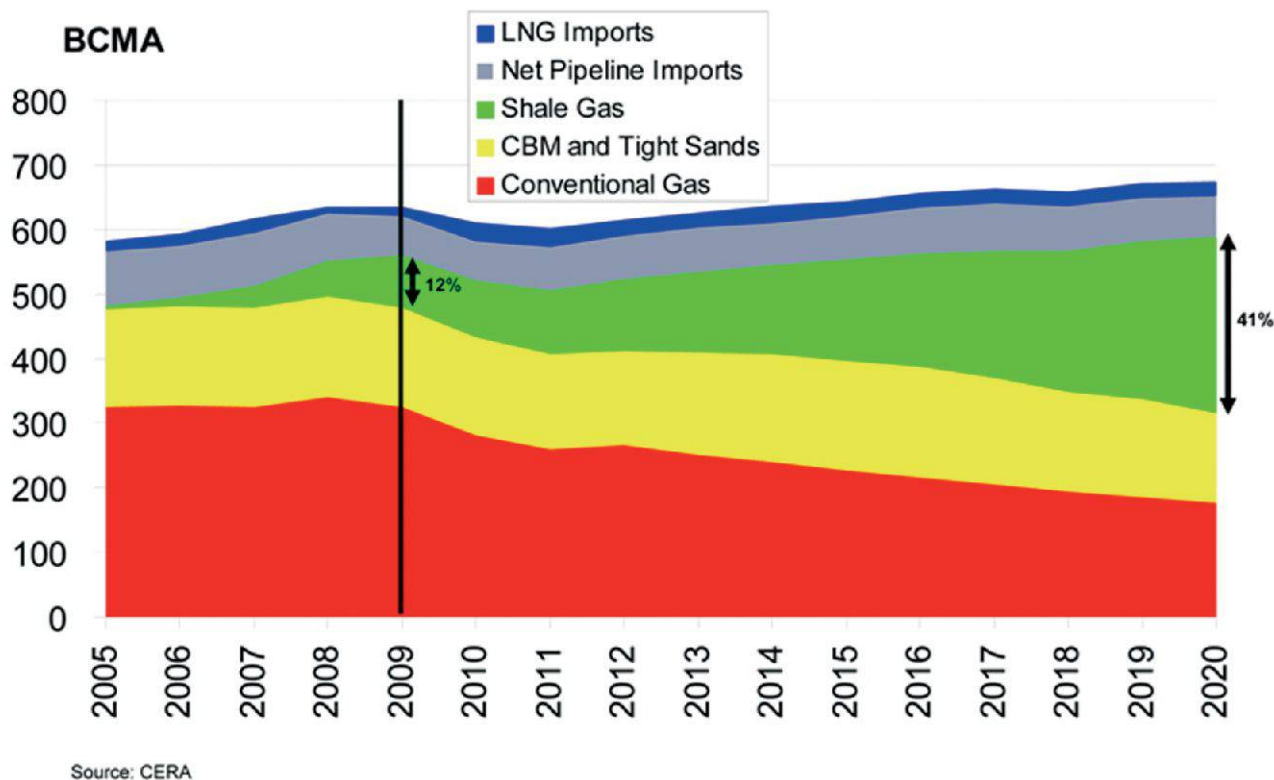
The exploration and commercial production of shale gas and other unconventional gas resources has initially been developed by small E&P companies predominantly without the participation of large players. In the past two years large Independents, National Oil Companies, like Statoil and the Majors, have successfully entered the game, often through multibillion dollar corporate acquisitions, e. g. Exxon bought XTO Energy (45 TCF) for 31 Billion USD (NY Times, 14 Dec 09).

As of 2010 the unconventional gas production in the US (CBM, Tight Sands and Shale Gas) exceeds the conventional production. Shale gas accounts for 12% of 2009 US production and is expected to rise to 41% in 2020 (Fig. 4).

Unconventional gas also has a dramatic influence on the reserve situation of the country. The proven gas reserves of the US have risen by some 27% from 2004 to 2009

(BP 2010); an even steeper increase to 35% over a 5-year period is expected when including the year 2010. This rise of proven reserves occurred in spite of very significant and rising production of some 330 BCM per year (Smith 2010, Midland College. Presentation at AAPG conference, New Orleans, 2010). The gas surplus has led to reduced imports from Canada and to a virtual collapse of the planned LNG import schemes (Fig. 5). It is likely that the US will be independent from additional imports of gas for several decades to come.

The collapse of the US LNG market requires that many LNG schemes, presently being planned or in construction worldwide, have to find new markets, which contributes to an oversupply in Europe.



**Fig. 4:** Impact of unconventional gas on the US gas supply. In 2010 unconventional gas is already covering more than 50 % of the total US production. Shale gas is expected to supply 41 % of the total US demand by 2020. [Source CERA, courtesy of Ken Chew, IHS, 2010].

## 5. Opportunities in Europe and the rest of the world

Shale gas plays are not unique to the US but are being developed in many other countries as well. However, it is unlikely that the extremely rapid development of these gas resources in the US can be duplicated in the short term in other places of the world. This is especially true for Europe.

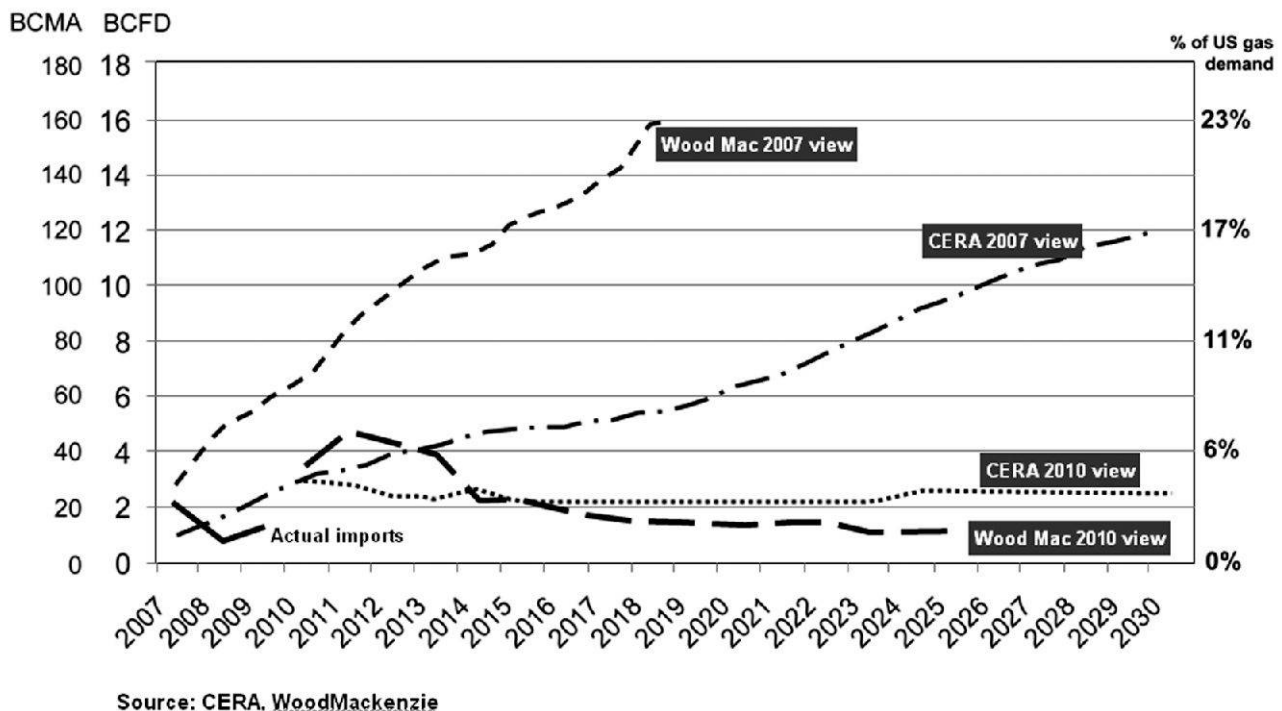
In Europe the focus is at present on Poland (Silurian Graptolite shales and Lower Carboniferous) and on the Liassic Posidonia Shale in Western Europe (France, Germany, Netherlands and Switzerland). The conditions for shale gas in the US cannot be transferred 1:1 to Europe for the following reasons:

- The geology in Europe is much more small-scaled and tectonically compartmented than in most of North America, where some of the suitable organic-rich shales cover areas of many 10 000 to > 100 000 km<sup>2</sup>.
- Shale gas development requires the drilling of thousands of wells. In the dense-

ly populated areas of Western Europe this would be a major challenge.

- Europe has generally a more stringent environmental legislation and more difficult approval processes for drilling operations.
- Development costs in Europe are considerably higher: Europe does not have a well developed, diversified and highly competitive service industry for onshore activities that would allow drilling and completion of long and multi-fraced horizontal wells at the costs typical for North America (5 – 10 Mio USD).
- In Europe, government take generally exceeds the fiscal charges and land fees which are customary in the US.

In other parts of the world, large shale gas developments will predominantly occur in areas with major conventional oil and/or gas production. Big gas provinces, like Siberia,



**Fig. 5:** The dramatic impact on LNG imports. Predictions in 2007 forecast a very substantial LNG import of up to 25 % into the US by 2020. Present forecasted LNG import volumes by the same institutions are negligible. [Courtesy of V. Neumann, Gazprom Germania 2010].



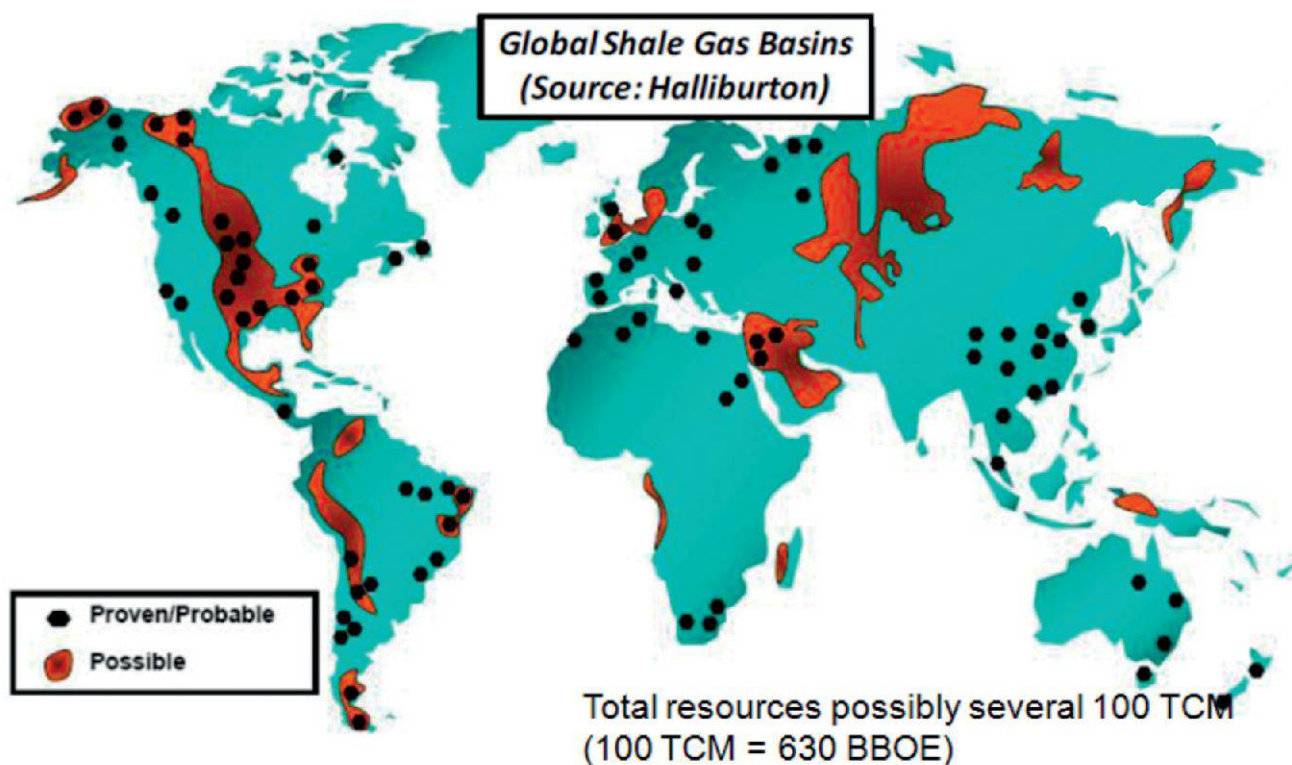
the Persian Gulf or North Africa, also have – by necessity – large, regionally extensive volumes of rich, mature to post-mature source rocks, the precondition for shale gas exploration. In these areas shale gas will become a major theme as and when cheap and technically easy conventional gas production is on decline (Fig. 6).

## 6. Implications for world energy supply

The rise of unconventional gas has a profound impact on the gas supply situation of the world. A conservative estimate of the unconventional gas resources identified today indicates total resources of 3000 – 4000 TCF, a volume identical to the total cumulative world gas production up to date of 3300 TCF (Ken Chew, IHS, 2010, Figs. 7 and 8). Given the fact that large potential resource areas, like Siberia, the Middle East and North Africa have hardly been evaluated, the shale

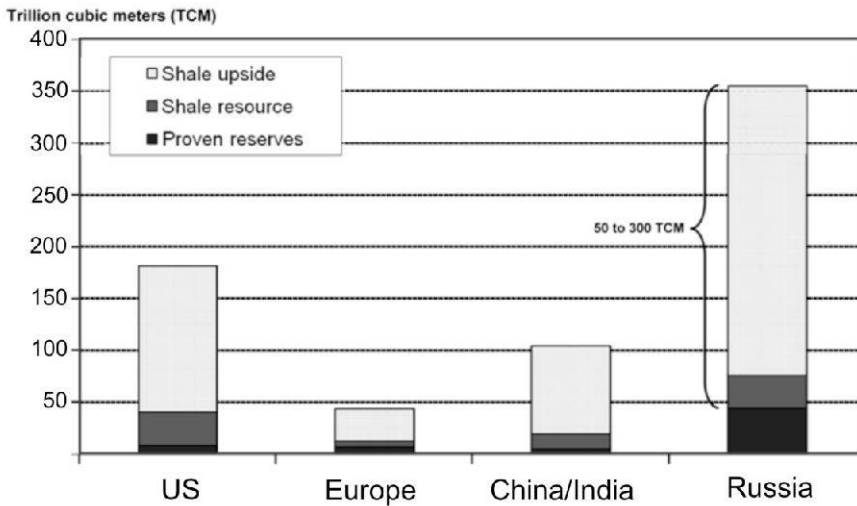
gas resources could well amount to a multiple of the above volumes.

The rise in unconventional reserves and resources comes on top of a significant increase that has been observed in recent years in conventional proven reserves, in resource growth in fields and in exploration expectations. The estimates of IHS for global gas resources have increased by some 20% from 2005 to 2008, equivalent to an additional 24 years of world gas demand in 2008 (Fig. 8). The much more comfortable reserve situation, and especially the rising US domestic production, have led to a decoupling of gas from oil prices on the world spot markets as from early 2009 (Fig. 9). This has generally been attributed to the impact of the 2008 – 2009 financial crisis on energy demand. However, a careful analysis of the background indicates a more likely fundamental structural change: gas is now in direct competition to oil and the link to oil is likely to weaken further.



**Fig. 6:** Areas of proven/probable and possible gas shale occurrences worldwide. Missing are the Silurian source rocks of North Africa. [Data by Halliburton, map courtesy of V. Neumann, Gazprom Germania].





Source: BP Statistics Review 2008; Woodmac, CERA, and other industry estimates

**Fig. 7:** Estimates for potential shale gas resources and upside for selected areas. Note that important areas like Middle East and Africa are missing. [Data courtesy of J. Hattinger, Gazprom US, compiled 2009 from BP Woodmac, CERA and other sources].

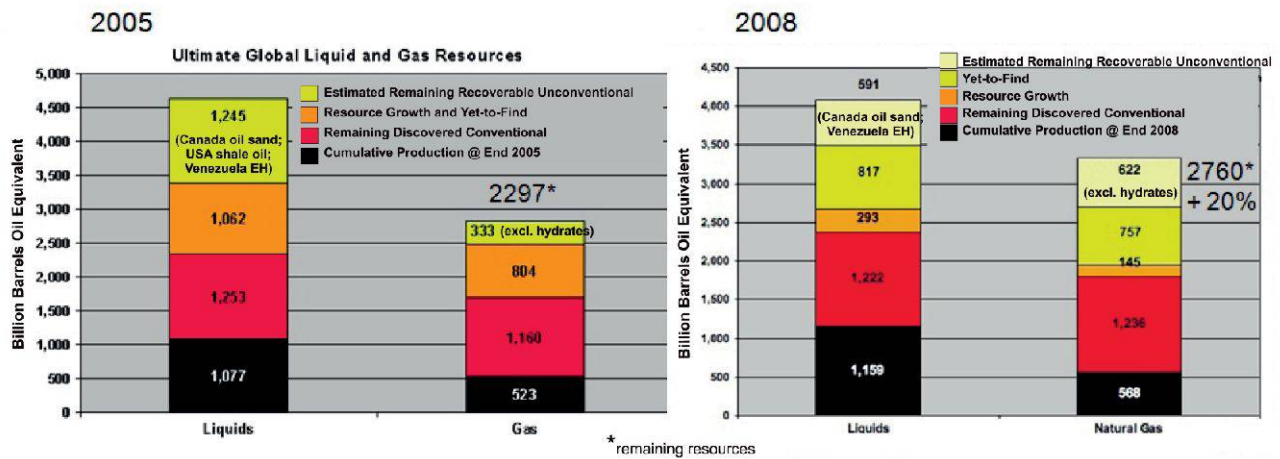
## 7. Conclusions

- Unconventional plays have become the main source of domestic gas production in North America, driven recently by the strong increase in shale-gas production.
- The breakthrough of unconventional plays into economically successful ventures has been made possible by step changes in technology (horizontal drilling, fracking/stimulation and seismic imaging).
- For the first time new technologies allow the E&P industry to tap into the very large volumes of oil and gas that have not reached conventional traps but have remained stranded in low permeability «wastezones» (low permeability rocks). These unconventional reservoirs might contain a multiple of the hydrocarbon volumes trapped in conventional plays.
- The parameters of the gas plays currently developed in the US cannot be extrapolated unconditionally to other parts of the world, but large shale gas resources have to be expected in all major conventional gas provinces of the world.
- The size of unconventional gas resources is at present equivalent in volume to the total cumulative gas production of the world up to today but could eventually be much larger than the presently known world reserves and resources.
- Gas is likely to become the main fossil fuel of this century and beyond, replacing oil and possibly coal.
- The dramatic rise of unconventional gas in the US (over 30% increase of proven reserves in 5 years) is having a major

	In place TCF	Recoverable TCF (present technology)
Coalbed Methane (CBM)	~ 5000–7000	~ 700
Tight Gas Sands	>>8000	~ 1350
Shale Gas		1000–2000
<b>Total</b>		<b>3000–4000</b> could be a multiple

Total cumulative world production to end 2009: ~ 3300 TCF

**Fig. 8:** Total estimated recoverable resources of unconventional gas worldwide. [Data courtesy of K. Chew, IHS].

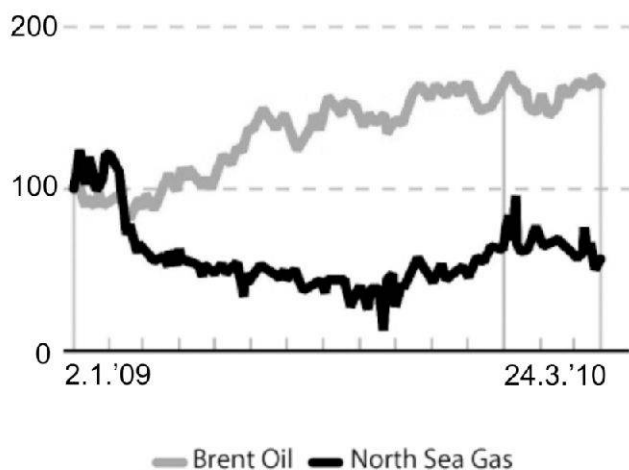


**Fig. 9:** The rapid growth of worldwide gas resources. Estimates of total recoverable gas reserves and resources grew by 20% in 3 years between 2005 and 2008 in spite of growing production. Resource growth since 2008 is likely to be of similar magnitude. [Courtesy of K. Chew, IHS].

impact on the outlook for global reserves. It illustrates how difficult it is to predict the reach of hydrocarbon resources. Future availability of hydrocarbons will be largely controlled by technology, price, production capacities/investments and, most importantly, political/regulatory measures (e. g. CO<sub>2</sub> constraints).

- Against the backdrop of the very large remaining unconventional HC resources the reach of fossil fuels is less determined by the geologically available volumes in the ground than by the question «can we afford it?» or «do we want it?», from the point of view of economics, environmental considerations and political dependency. The answer to this question will be strongly influenced by the price and the availability of alternatives.

Relative development of spot prices of oil and gas 2009 - 2010



Source: Bloomberg

**Fig. 10:** Relative development of oil and gas spot prices in 2009 – 2010. The decoupling of gas from oil prices is likely to be a fundamental, structural change – reflecting the in-creasing gas to gas competition [Bloomberg, New York Mercantile exchange, 2010, web site].

### Acronyms and terms

B: Billion (10<sup>9</sup>); BOE: Barrel Oil Equivalent; BBL: Barrel; BCF: Billion Cubic Feet (10<sup>9</sup>); BCM: Billion Cubic Metres; CBM: Coalbed Methane; EIA: US Energy Information Agency; E&P: Exploration and Production; HC: Hydrocarbons; IEA: International Energy Agency; Industry: here: the oil and gas industry; LNG: Liquid Natural Gas; Majors: The group of the largest, multinational private oil and gas companies (Exxon-Mobil, Shell, BP, Chevron, Total); TCF: Trillion Cubic Feet (10<sup>12</sup>); TCM: Trillion Cubic Metres; TOC: Total Organic Content; SR: Source Rock; USD: US Dollar.



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